Fall 2019

Impacts of Agricultural Practices on Soil Quality and the Resulting Soil Conservation Implication in Kizanda Village, Lushoto Region, Tanzania

Sarah MacCormick

SIT Study Abroad

Impacts of Agricultural Practices on Soil Quality and the Resulting Soil Conservation Implication in Kizanda Village, Lushoto Region, Tanzania

Sarah MacCormick

Academic Director: Oliver C. Nyakunga

Academic Advisor: Houssein Samwel Kimaro

Kizanda Village, Lushoto District, Tanga Region, Tanzania

Bates College - Environmental Studies: Ecology and Earth Systems Major

Submitted in Partial Fulfillment of the Requirements for Tanzania: Wildlife Conservation and Political Ecology, SIT Study Abroad, Fall 2019

ACKNOWLEGEMENTS:

I would like to thank many people that made this study possible. Most importantly, I would like to extend my great gratitude to all the farmers that I interviewed in Kizanda. This study simply would not have been possible without their kindness and willingness to work with me. Next, I must thank my wonderful translator, Ashiraz Mhema, who connected me with farmers throughout Kizanda Village and accompanied me on the many hours of walking throughout the data collection process. I would also like to thank my amazing forest guide, Edy, who lead me through Mazumbai Forest. A special thanks goes to Zwena, who helped me process my soil samples in the kitchen and cooked amazing meals throughout our time in Mazumabi. Next, I would like to thank Oliver C. Nyakunga and Oscar Paschal for the support throughout the entire ISP process. I would like to also thank my advisor, Houssein Samwel Kimaro who helped me to sharpen my ideas. This study would not have been possible without the other students at Mazumbai, so I would like to give a huge shout out to Adam, Annika, Shannon, and Callie. I would also like to thank all the other staff for hosting us at the Mazumbai Chalet. In addition, Mama Juni very nicely checked in with all the students throughout the whole process and I would like to thank her for making all the students feel safe.

ABSTRACT:

This study examined soil conservation in Kizanda Village which is in the Lushoto District, Tanga Region in the West Usambara Mountains of Tanzania. In Tanzania, and more specifically, the rural montane area, agriculture is an important part of both social and economic development. Due to a reported high rate of land degradation in Tanzania, this development is threatened though the lack of soil conservation. This study conducted structured interviews with farmers in Kizanda through snowball sampling to collect information about local agricultural practices and farmers' perceptions on soil conservation issues. Soil samples were then collected from the corresponding farms (n= 63) and tea plantations (n=24) as well as within Mazumbai Forest Reserve (n=18) - a nearby privately protected 'pristine forest'. The soil quality of each sample was determined through the moisture content, soil organic matter content, sand to silt/clay ratio, and pH. Data was collected between November 7th and November 27th in 2019. It was found that 66% of farmers interviewed reported decreasing crop yields on their farms, 48% reported a decrease in soil quality, and 28% reported soil erosion as an issue on their respective farms. These responses highlighted soil conservation as an issue in Kizadna. Through an All Pairs Tukey HSD statistical test in JMP Pro, it was determined that soil in the uncultivated Mazumbai Forest Reserve on average had higher moisture contents than the soil from the cultivated farms and tea plantations. In addition, it was determined that samples from tilled farms had a lower quality (lower soil organic matter content and higher sand content) than samples from untilled farms. Similarly, samples taken near the cover crop mshai had higher organic matter contents than samples near no cover crop. Thus it is recommended to use mshai as a cover crop and no till farming in order to conserve soil quality.

Key Words: soil conservation, high montane agro-ecosystems, agricultural practices, Tanzania, West Usambara Mountains, soil quality, land cultivation

TABLE OF CONTENTS

INTRODUCTION:

Background:

With an increasing human population around the globe, food scarcity is accelerating as a global issue (Kideghesho, 2015). Food scarcity coupled with ecological deterioration due to climate change, land use change, and pollution is putting immense pressure on the global agricultural sector (Kideghesho, 2015). To meet the global food demand, more uncultivated land is being developed for food production (Mbaga-Semgalawe & Folmer, 2000). The combination of heavy agricultural land use and cultivating new plots is degrading land around the globe at an alarming rate (Mbaga-Semgalawe & Folmer, 2000). Land degradation simply refers to the land decreasing it's potential to support life (World Bank, 2019). Land degradation impacts crop growth primarily through soil erosion (MTNRE, 1994). Soil erosion can lead to loss of nutrients in the soil including nitrogen, phosphorus, and potassium, the loss of organic matter and moisture retention ability, and lowered quality of the physical structure of the soil (Lal, 1985). Globally, 3.2 billion people are already reportedly being impacted by land degradation, with a predicted increase to 4 billion by 2050 (IPBES 2018). In addition to land deterioration, agricultural expansion is the main driver of deforestation (MTNRE, 1994). Deforestation contributes to many ecological crises including loss of biodiversity, carbon sinks, and useful resources (World Bank, 2019).

Sub-Saharan Africa is an example of a place that heavily relies on agriculture for social and economic development (Mbaga-Semgalawe & Folmer, 2000). Tanzania in particular is highly dependent on agriculture, with it contributing to 30% of the country's GDP and 80% of employment (FAO, 2014). Tanzania is categorized as having one of the fastest rates of deforestation worldwide, loosing 0.8% of forested land annually (World Bank, 2019). Hosting many biodiversity hotspots, including the Usambara Mountains where this study was conducted, the deforestation rates in Tanzania are cause for great concern (Burgess, 2007). The dependance on the land through agriculture makes these threats more concerning and highlights the vulnerable position Tanzania is in, exacerbated in the rural areas with even more dependance on the land.

Thus, in Tanzania, there is a need to mitigate agricultural land expansion. In order to do so, food production must be sustainable and efficient. A study in the Western Usambara Mountains categorized farms into sustainable land management practices and then tested each farm's soil for a range of different soil quality indicators (Wickama et al., 2014). The study found that the farms that used ample animal manure, bench terraces, and minimal tilling had the highest soil nutrient content and the highest crop yields (Wickama et al., 2014). Wickama et al.'s study worked to add information to the collection of studies done on how small-scale agricultural practices impact the soil. This study aims to analyze specifically how Kizanda Village fits into this picture. This study will first determine the impact of land cultivation on soil quality in and around Kizanda, and then examine how agricultural practices affect the soil quality in terms of soil conservation.

Soil quality can be measured through many different indicators including biological, physical, and chemical properties of the soil., This study will take into account four indicators to get a general idea of the soil quality for each sample: pH of the soil, soil organic matter, soil texture, and moisture content. The pH of the soil reflects the nutrient availability of the soil (Winowiecki, 2015). In general, a neutral pH, around 7 is ideal for crop growth (USDA, 2001). The soil organic matter content is all material in the soil produced by any living organism (Winowiecki, 2015). For example, this can include dead plant material, fallen fruits, or added animal manure. The amount of organic matter in the soil reflects availability of important nutrients for vegetation growth (Winowiecki, 2015). In addition, soil organic matter works in tandem with the soil structure to create aggregates (clumps of soil); residue left by bacteria act as a glue to hold soil aggregates together (Winowiecki, 2015). Aggregates are important for aeration and infiltration (USDA, 2001). Lastly, soil organic matter reflects the decomposition rate within the soil (Bot & Benites, 2005). In general the higher the soil organic matter content, the healthier the soil is considered (USDA, 2001). Soil texture, or soil composition is dependent on the size, shape, and sorting of mineral particles (Lindbo et al, 2012). The size is measured on scale of fine to coarse with sand, silt, and clay being 0.06-2 mm, 0.002-0.005 mm, under 2 um respectively (Lindbo et al, 2012). Soil texture reflects the porosity, permeability, infiltration, and water/nutrient holding capacity (Lindbo et al, 2012). Clay rich soils protect the soil from leaching away nutrients due to water retention abilities. They also allow for pants to take up the nutrients within the soil because cations are suspended outside of the particle due to their structure (Chapman, 1965). The ideal soil texture is categorized as loamy soil and contains around 40% sand, 40% silt, and 20% clay (USDA, 2001). The moisture content of the soil is important because it reflects information on water holding capacity of the soil. Soil with very little moisture retention will often exhibit a low soil moisture content. The combination of these parameters will provide a rounded quantification of soil quality (Winowiecki, 2015). The following sections include more specific objectives, the hypothesis, a site description, specific methods, results, discussion, and finally a conclusion.

Objectives:

This study aims to answer the following specific questions about soil conservation in Kizanda Village.

1. Does land cultivation impact the soil quality? If so, how?
2. What agricultural practices are used in Kizanda?
3. Do the agricultural practices used in Kizanda differentially impact soil quality? If so, how?
4. What other factors impact the soil quality?

Figure 1 - Location of the Eastern Arc Mountains throughout Tanzania and Kenya

Source - (EAMCEF). "LOCATION OF THE EASTERN ARC MOUNTAINS ." BRIEF PROFILE OF THE EASTERN ARC MOUNTAINS CONSERVATION ENDOWMENT FUND, 2009, pp. 1–1.

Hypotheses:

In hypothesis, land cultivation generally lowers soil quality, shown by lower soil organic matter content, moisture content, and pH and a higher sand content (above 40%). In addition, the agricultural practices of the farms will differentially impact the soil quality, some will maintain a high soil quality will theres will be associated with a low soil quality. Similarly, there are other factors that impact soil quality such as slope steepness and elevation.

METHODS:

Site Description:

This study was conducted in Kizanda Village which is found in the Lushoto District within the Tanga Region of Tanzania. Kizanda is in the West Usambara Mountains; these mountains make up part of the Eastern Arc Mountains, which run down the eastern part of Kenya and Tanzania (Galford, 2013) (Fig. 1). The West Usambara Mountains are part of the high montane ecosystem, similar to the ecosystems of other mountains in Tanzania like Mount Kilimanjaro and Mount Meru (Galford, 2013). Mount Kilimanjaro and Meru are geologically relatively young mountains with extremely fertile volcanic soils (Galford, 2013). However, The West Usambaras have ancient, more acidic soils, making the area less fertile for agriculture (Galford, 2013). The soils of the West Usambaras have been formed over the last billion years through a combination of faulting, uplifting, and erosion of the largely pre-cambial basement rocks of the Usangaran belt (Maboko and Nakamura, 2002).

Kizanda is located adjacent to Baga Forest Reserve, which is a restricted land use area controlled by the government; it is also very close to Mazumbai Forest Reserve which is an even more restricted, privately-patrolled protected forest. Historically, Mazumbai Forest Reserve was both a forest reserve and a tea plantation controlled by Swiss colonists (S. Kiparu, personal communication, November 2019). Now, Mazumbai Forest Reserve is owned by Sokoine University of Agriculture (S. Kiparu, personal communication, November 2019). The proximity to restricted-land use areas puts further stress on farms because land expansion is limited. The land of the West Usambara Mountains has been used for farming for thousands of years (Newmark 1998). In the 1950s, land was taken up by European settlers to establish tea plantations (Mbaga-Semgalawe & Folmer, 2000). Historical colonial control has contributed to land pressure due to land alienation (Mbaga-Semgalawe & Folmer, 2000). In 1947, the British colonial Government recognized the land degradation that was taking place in the West Usambara Mountains and implemented the Land Usage Schemes. The new schemes outlined soil conservation techniques with an aim to rehabilitate eroded and degraded areas of land and to prevent further damage (Mbaga-Semgalawe & Folmer, 2000). The land Usage Scheme included soil conservation practices such as no steep-slope land cultivation, bench terraces, contour cropping, demarcation of forest boundaries, and tree planting (Mbaga-Semgalawe & Folmer, 2000). This new set of rules were enforced by colonial law and led to passive resistance against the schemes by the inhabitants of the West Usambaras (Kimambo, 1991). After gaining independence in 1961, famers in the West Usambaras adapted soil conservation techniques to include mulching, crop rotations, intercropping, and minimal tillage (Mbaga-Semgalawe & Folmer, 2000).

Within Kizanda specifically, people heavily rely on the land for food and their livelihood. More than 80% of all people living in Kizanda are farmers, making Kizanda extremely vulnerable to land productivity changes (A. Mhema, personal communication, November 2019). Another study conducted in Kizanda in 2017 examined farmers' adaptations to climate change (Smith-Helman, 2017). Smith-Helman reported that Kizanda farmers are experiencing decreasing crop yields over time (2017). In some cases, this is leading to more land being deforested for cultivation which, in turn, is leading to soil exhaustion and soil erosion (Smith-Helman 2017). The soils in Kizanda were found to be primarily humic ferralitic soil within the protected Mazumbai Forest Reserve (D'Hoore, 1964). However, in the tested agricultural lands of Lushoto District, the soils were primarily classified as humic nitosols (Lundgren, 1980). These red to yellowish soils tend to have a high content of sand and clay, with a low content of silt (Lundgren, 1980). Lundgren classified the soils to be relatively infertile due to a low percentage of organic matter in the soils (Lundgren, 1980).

This study collected soil samples at three different categories of sites (Fig. 2). The first category being vegetable and fruit farms, throughout this paper, this category will be referred to simply as ‘farm’. All of these farms were intercropped, meaning that they had several different crops growing on the same plot of land. The next category for sample collection was tea plantations. These plots of land tended to be further away from the main part of Kizanda village. Thought the paper, this category will be referred to as ‘tea plantations’. The last category for sample collection was the Mazumbai Forest Reserve, as explained before this forest reserve is heavily protected and is accepted as a ‘pristine forest’. This category will be referred to as ‘Mazumbai Forest Reserve’ throughout the paper.

Figure 2 - Photos of the three soil sample site categories, on the left is ‘farm’, in the middle is ‘tea plantation’, and on the right is ‘Mazumbai Forest Reserve’.

Methodology:

The data collection period for this study was 20 days, starting on November 7, 2019 and ending on November 27, 2019. This study utilized snowball and convenience sampling to connect with farmers in Kizanda. A study done by Robinson explains that snowball sampling is one strategy used to recruit interviewees by asking the previous interviewee for recommendations (2014). This method of finding interviewees ensured that the farmers would feel comfortable talking about their farms and allowing for their farms to be sampled because there was usually a mutual friend or family member involved. Interviews were conducted in a mix of Kiswahili and Sambaa languages translated into English. The interviews were structured primarily with binary questions (Appendix I).

After completing the interviews, three soil samples from each farm or tea plantation were collected. Sampling sites were chosen to represent the heterogeneity within the farms (USDA, 2001). Each sample site was scrapped with a trowel to remove any leaf litter or other big organic material such as sticks or weeds. The soil was collected from depth of ten centimeters (USDA, 2001). Each sample was labeled and placed into a plastic Tupperware. Metadata including what crops were near the sampling site, slope aspect, relative slope steepness, elevation, proximity to the forest edge or cover crops (if applicable) were all recorded. The same soil collection methods were implemented for the samples collected in Mazumbai Forest Reserve. Sampling sites within Mazumbai Forest Reserve were chosen based on similar elevations to the farms and tea plantations.

After the soil samples were collected, they were analyzed for the combination of soil quality parameters discussed in the background section. The soil samples were first weighed and placed into tinfoil cups. Then, the samples were dried in a wood fired oven for 3 hours (Reves-Sohn, 2018). After the samples were completely dry, they were weighed again. The water content was then calculated using these two weights. Dry soil from each sample was saved after this initial drying process to be analyzed for additional parameters later. After being reweighed, any large organic matter was removed from the samples and then placed on a wood fired stove for 6 hour to remove any additional organic particles (Reves-Sohn, 2018). After this process, the soil organic matter content was calculated. With the dry soil saved from earlier, two additional parameters were tested: the texture of the soil through a sand to silt/clay ratio analysis, and if the soil was acidic or not. First, the samples were ground up to break apart any aggregates and then funneled into a small clear plastic bottle. Then a little bit of water was added to form a muddy consistency and the height of the mud was recorded (Reves-Sohn, 2018). Then more water was added, up to where the bottle began to taper inwards. After 30 seconds of shaking to ensure thorough mixing, the bottle was set for 30 seconds. After the settle period, the sand particles fell down and settled at the bottom with the clay and silt particles still suspended in the water above. The height of the sand was measured. With these two measurements, the relative composition of sand to silt/clay was calculated in percentage form (Reves-Sohn, 2018). And lastly, after an additional few minutes of settling, a Litmus Blue pH paper was dipped into the water and it was determined if the sample was acidic or not based on the color of the paper strip (Gillespie, 2019).

To analyze the results, simple charts were made in Apple's Numbers to quantify the farmers' responses to the interview questions. Using JMP Pro 14, more complex graphs were made to

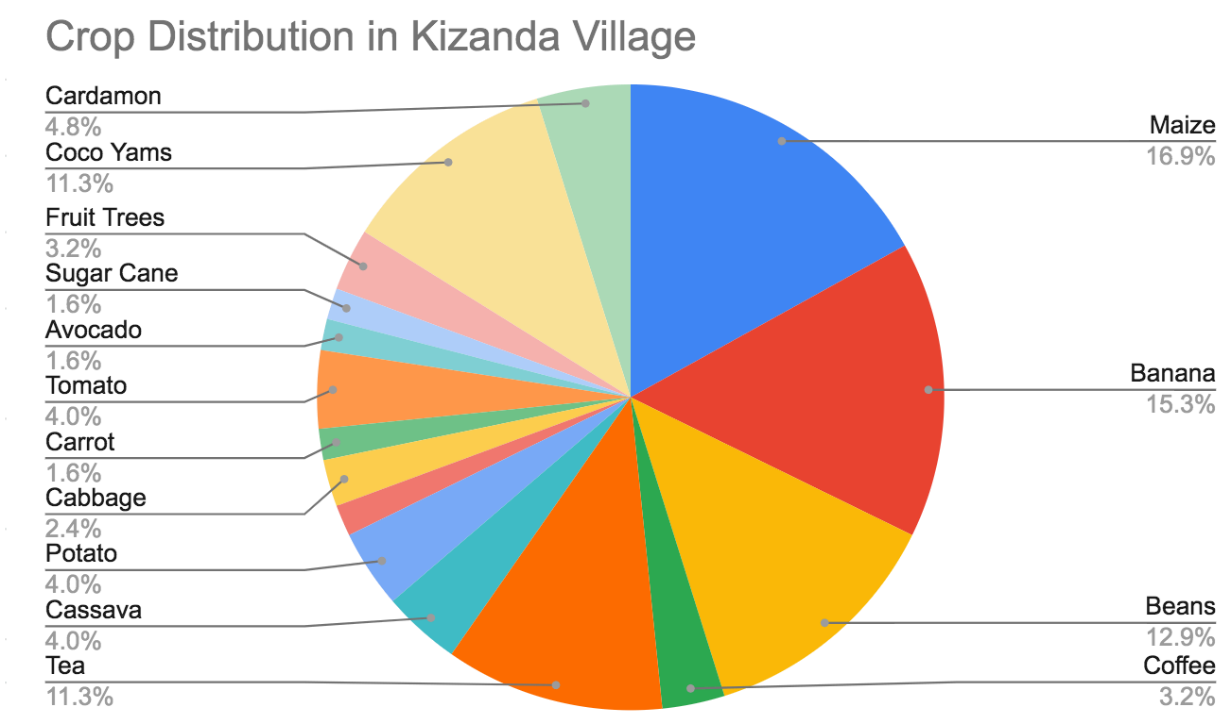


Figure 2 - This pie chart shows the frequency of individual crops grown by each sampled farmer.

visualize the soil quality based on the three study site categories, the different agricultural practices implemented, and the general factors about the soils. Additionally in JMP Pro 14, statistical analyses were preformed on the same relationships between variables; tests included one-way ANOVA to compare differences of means between groups of data, All Way Tukey HSD test to compare lots of groups of means to each other at the same time, and correlation probability tests to examine relationships between continuous data. The All Way Turkey HSD tests were interpreted through a connected letters report.

RESULTS:

All of the famers interviewed over the course of this study were more than willing to answer the questions and allow sample collection on their farms. The results of the interviews revealed a more clear picture of farming in Kizanda. The primary crops grown by the sample of the Kizanda farmers are maize, coco yams, bananas, and tea (Fig. 2). As shown in Figure 4, two thirds (66%) of the farmers reported that their crop yield has decreased over time. Additionally, a little under half (48%) of the farmers reported a decrease in soil quality of their farms over time (Fig. 4). When asked about their soil quality, most farmers referenced the amount of fertilizers they needed to use to support the crops as the only indicator. Only about a fourth (28%) of the farmers reported that soil erosion was an issue on their farms (Fig. 4). In terms of agricultural practices that were inquired about, around half (52%) of the farmers used cover crops. The cover crops used included mikuyu, mshai, and mvumu which are all trees, and tughutu which is a shrub (translations of cover crops can be found in Appendix III). Most of the cover crops were intentionally planted by the farmers, but a few said that the trees were there before they began farming. Crop rotations were implemented by 45% of the farmers, and the same amount of farmers reported that they till their land (Fig. 5). All of the tilling in Kizanda is done by a hand held tool. 79% of the farmers use intercropping. All of the farmers that farmed a variety of crops (‘farms’) used animal manure and very quickly responded to that question as if it was obvious. However, none of the tea plantation farmers used animal manure. Around a third off the farmers (31%) reported using chemical fertilizers (Fig. 3). Urea, Dup, and NPK were examples of some of the chemical fertilizers used. 24% of famers reported using pesticides on their crops (Fig. 3). Farmers mentioned Perfecton, Sicron, and Boost up for pesticides they used. Only 14% of farmers reported using herbicides; the only herbicide mentioned during interviews was Roundup (Fig. 3). Most of the farmers couldn’t remember the names of the chemicals they use on their farms, so no statistical analysis was preformed on specific chemicals because it would not represent what was actually used on the sampled farms.

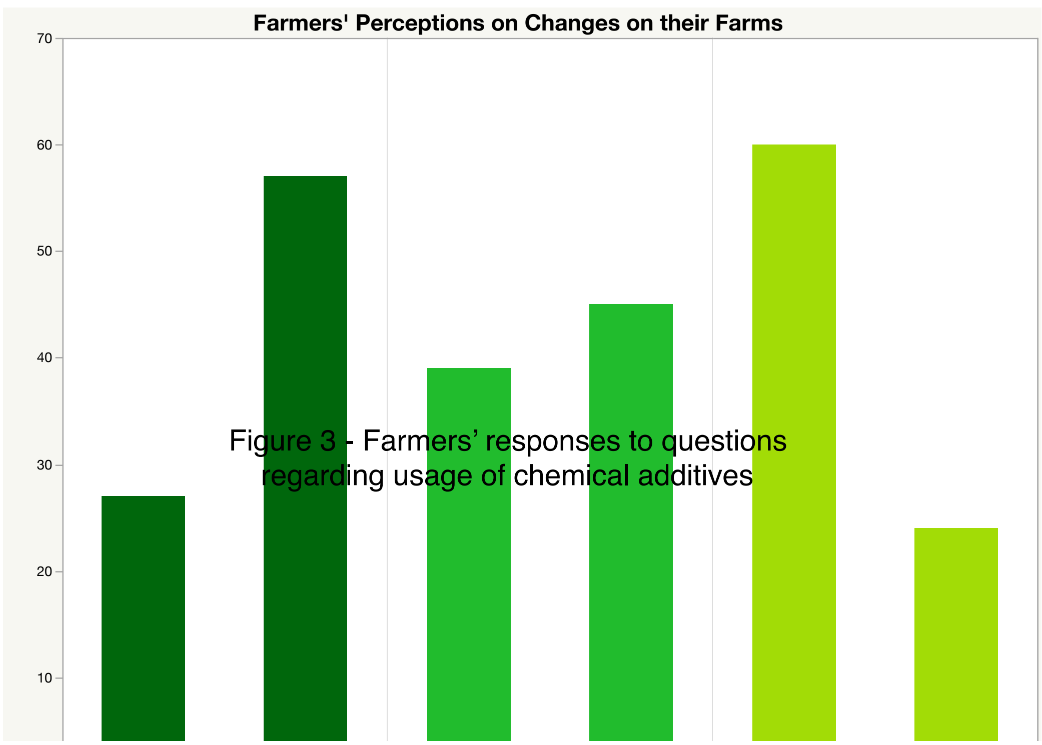
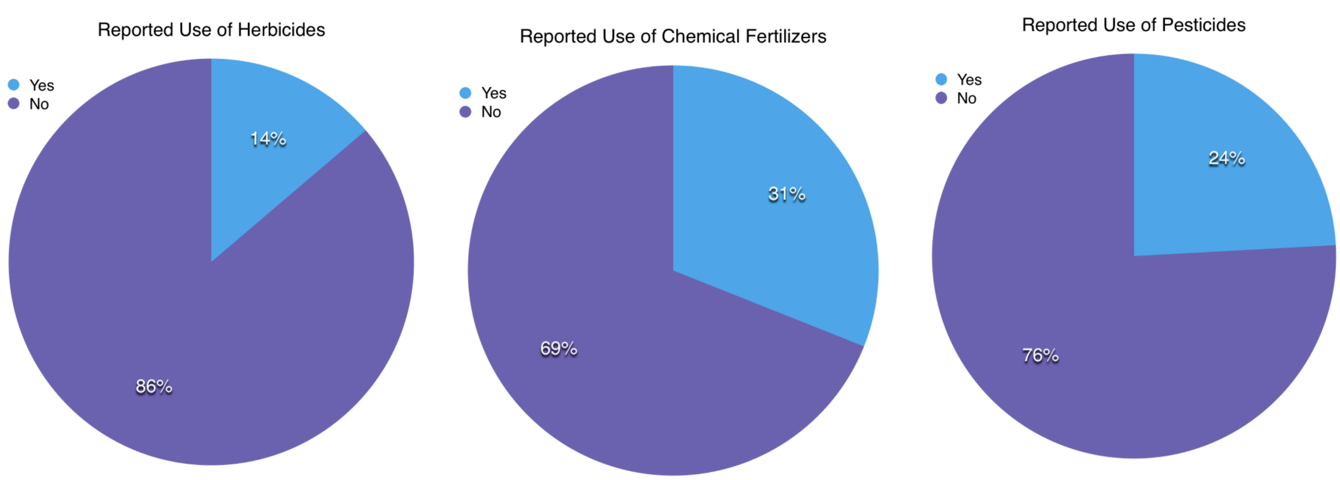


Figure 3 - Farmers' responses to questions regarding usage of chemical additives



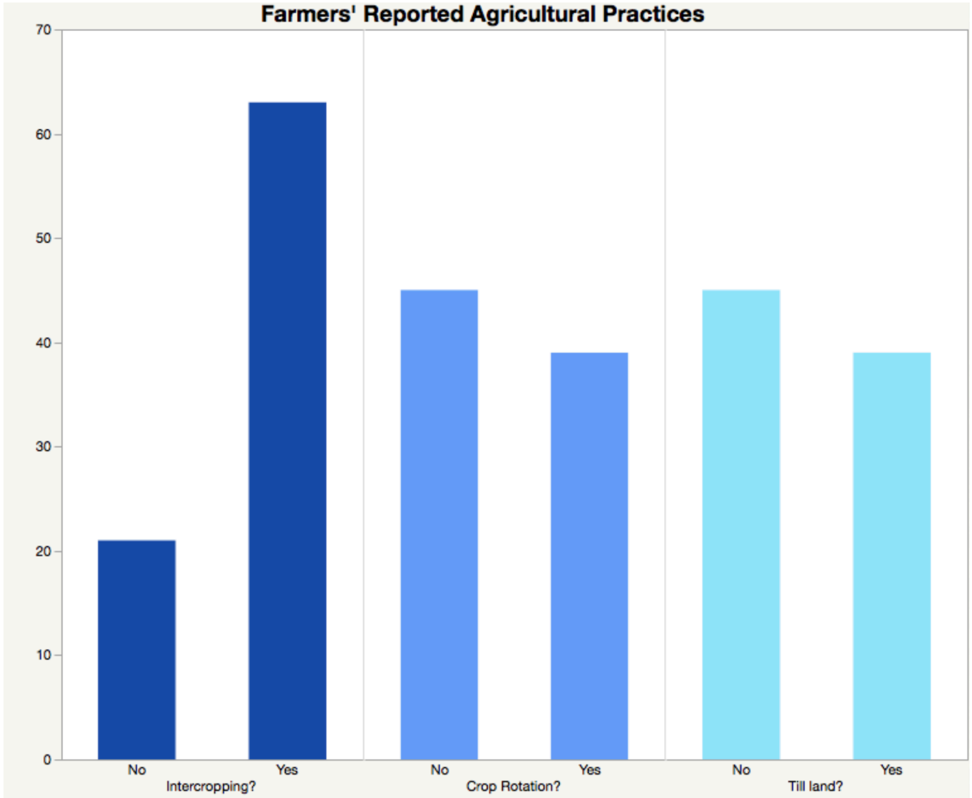


Figure 5 - Farmers' responses to questions regarding their agricultural practices.

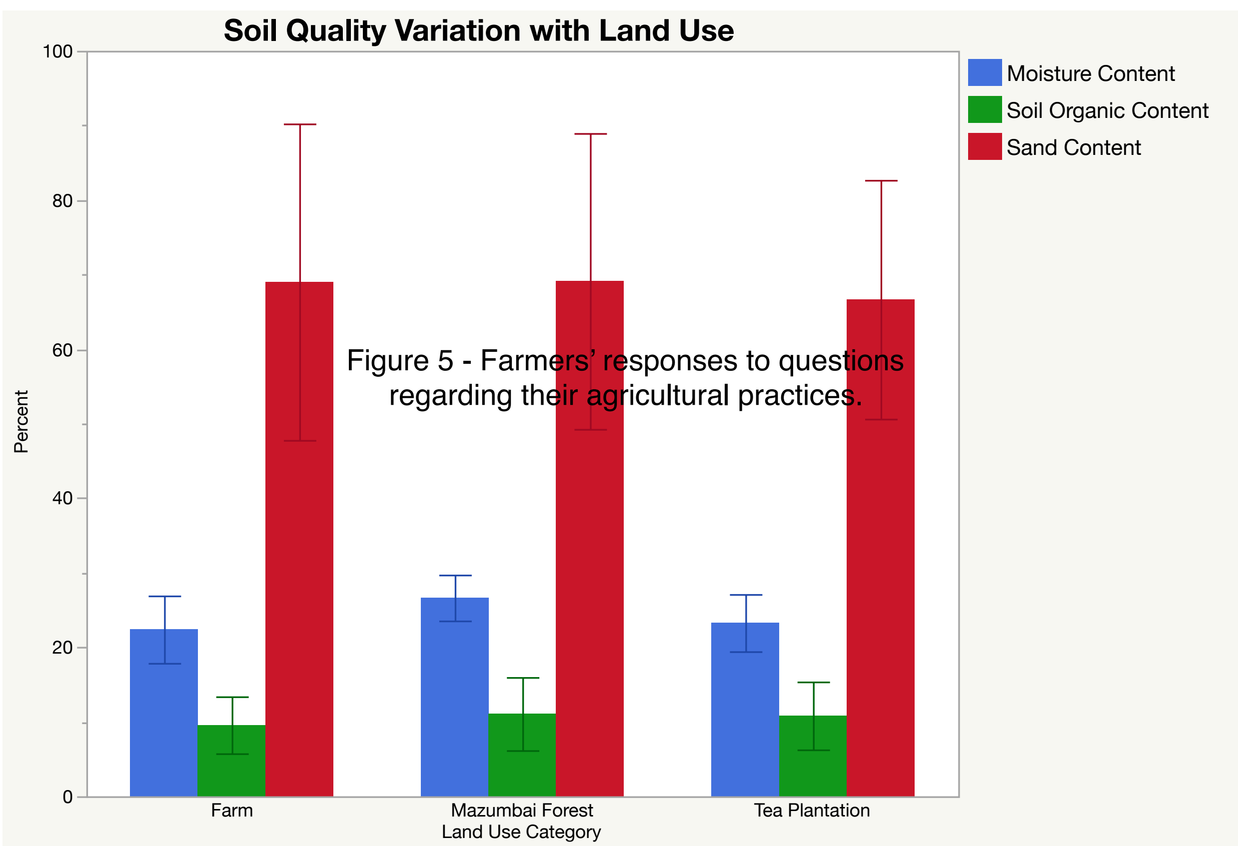


Figure 6 - A visualization of the relationship between average moisture content, soil organic matter, and sand content between different land use categories. Error bars are represented with the standard deviation.

Following are the results for all soil samples collected over the course of this study. The samples from Mazumbai Forest Reserve, the tea plantations, and the other farms had moisture contents ranging from 14.2% to 36.3%. The standard for moisture content found by a past SIT student in soils at Mazumbai was found to be between 5.0% and 31% which mostly encompasses the moisture content found in this study (Reves-Sohn, 2018). The soil organic matter content were ranging from 1.84% to 29.7%. The standard for soil organic matter found in the Amazon rainforest (which has a similar ecosystems to the West Usambaras) is 18.2% - 29.2% (Durigan et al., 2017). The soil organic matter found in this study encompass a much larger range, but do not exceed the standards top range. The sand content of the samples are ranging from 33.3% to 96%. The sand content standard found in the Lushoto District was 2% - 80% (Massawe et al., 2018.) The standard is a much larger range than the sand content found in this study and has a lower maximum percentage. The analysis of the soil samples with litmus blue pH paper showed that all samples were not acidic. The standard range for pH in the Lushoto District is 3.9-81, since this study did not obtain specific numerical pH values, it is unknown if the standard encompasses this studies pH(Massawe et al., 2018). Interestingly, the only correlation between these three soil quality parameters is between soil organic matter content and sand content. The correlation probability is significantly different between these two variables, with a correlation probability p-value of 0.0001, however, this correlation is not strong because the variable's linear fit produced an R^2 value of only 0.134. All of the following statistical analyses utilized an alpha value of 0.05 which corresponds to a 95% confidence level and resulting p-values are only reported below if they are less than the alpha value.

In order to determine the effect of land cultivation, the soil quality parameters were tested across the three different study site categories. The samples from farms and tea plantations being in the cultivated land category and the samples taken from the Mazumbai Forest Reserve being in the uncultivated land category. The land use categories were tested for significant difference in the three soil quality parameters using an All Pairs Tukey HSD test. The only significant difference found was that the Mazumbai forest samples had a higher moisture content than the tea plantation and other farm samples (with p-values of 0.0292 and 0.0007 respectively) (Fig. 6).
In order to determine the relationship between general factors and soil quality, the following data analyses was preformed. Metadata variables were tested to see if they had significant differences

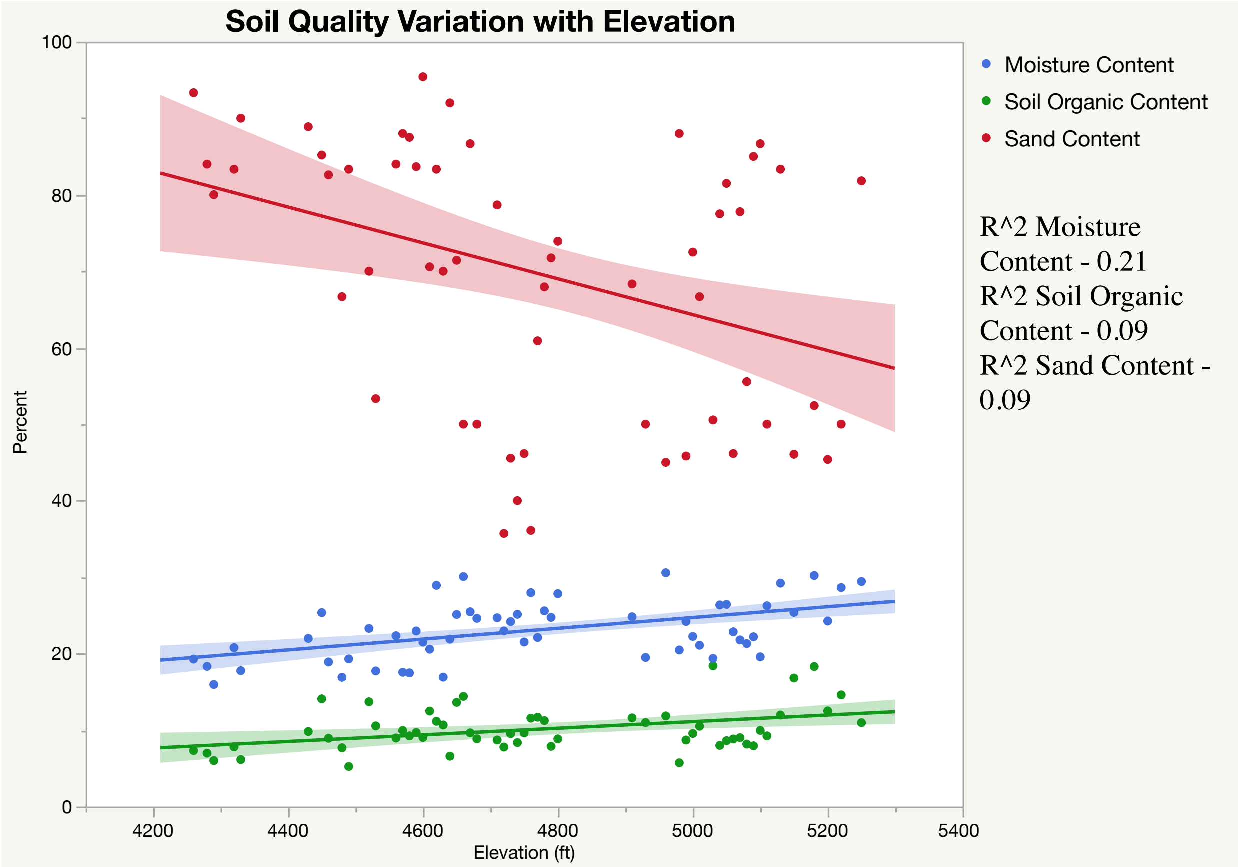


Figure 7 - A visualization of the relationship between moisture content, soil organic matter, and sand content with a changing elevations. All soil samples taken thought out this study were included in the chart.

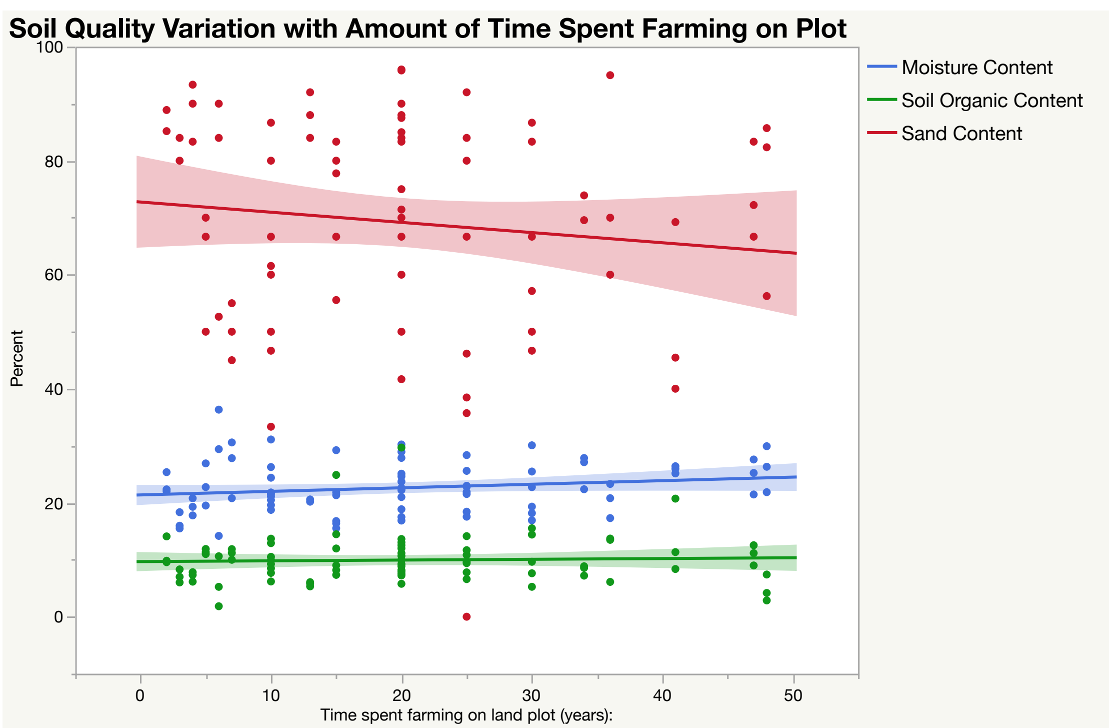


Figure 8 - A visualization of the relationship between moisture content, soil organic matter, and sand content with variation in the number of years spent farming on the specific plots.

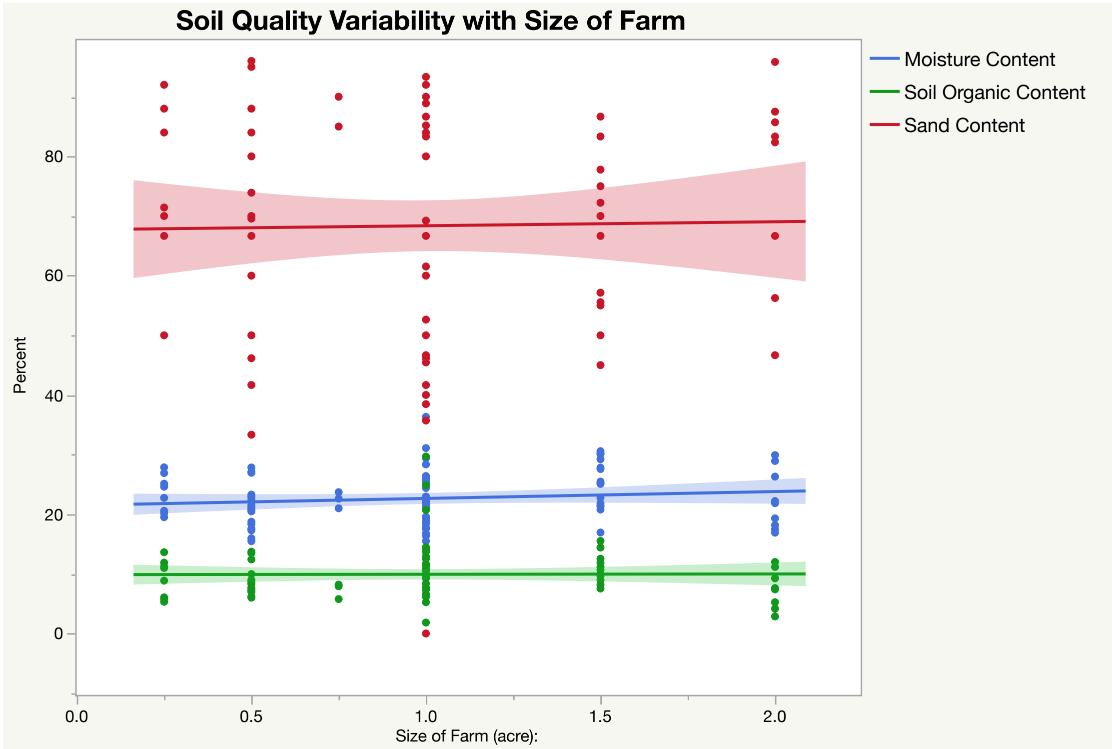


Figure 9 - A visualization of the relationship between moisture content, soil organic matter, and sand content with variation in the size of the farms.

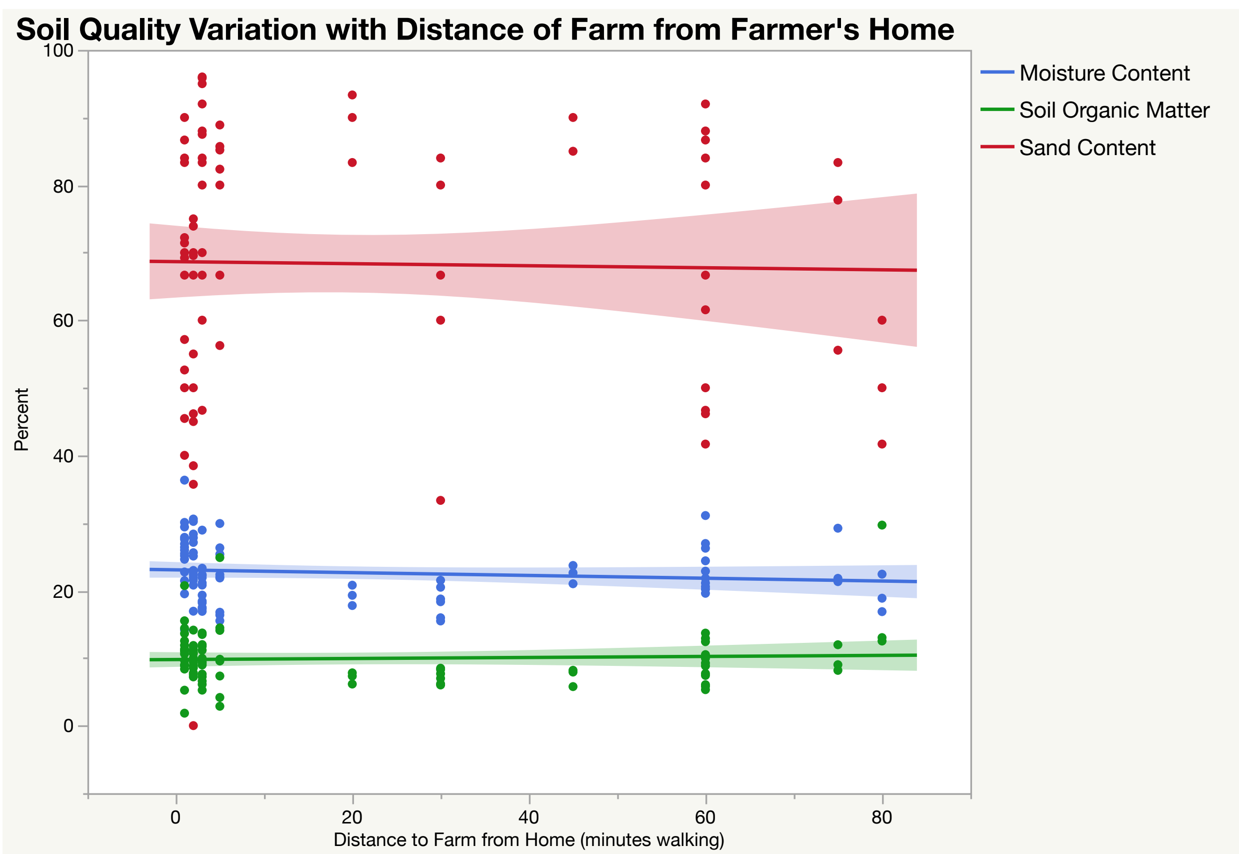


Figure 10 - A visualization of the relationship between moisture content, soil organic matter, and sand content with variation in the distance to the farms from the farmers' homes.

between the three soil quality parameters using an All Pairs Tukey HSD test. This test analyzes for significant differences between multiple groups of data, presenting the findings using a connecting letters report. Different sample site slope aspect presented no significant difference for soil organic content or sand content. However, the moisture content values for the south-facing sampling sites were significantly lower than the northwest/northeast/east/north facing aspect sampling sites (with p-values of 0.001, 0.0003, 0.0123, and 0.0202 respectively). The proximity to the edge of the forest didn't have any significant differences on the soil quality parameters. The relative slope steepness showed no significant difference in terms of soil organic matter content or moisture content. However, the sand content did show significant differences based on the relative slope steepness. The "steep slope" category samples had significantly lower percent sand content compared to the other slope categories. In addition, the "medium-steep" slope category was significantly higher in sand content than the rest of the slope categories (with a p-value of 0.0300). The last metadata parameter tested was the elevation using a scatter plot, and then a correlation probability test. The R^2 values for the relationship between elevation and moisture content, soil organic matter, and sand content are 0.21, 0.9, and 0.9 respectively. The correlation probably for elevation and moisture content, soil organic matter, and sand content are all less than 0.001 meaning it is not a significant relationship (fig. 7). The time spent farming on the specific plots, the size of the farm, and the distance to the farms from the farmers homes all showed no significant correlations between the three soil quality parameters (fig. 8, fig. 9, and fig. 10 respectively).

Next, the samples were categorized based on the agricultural practices used where they were collected and the resulting three soil parameters were analyzed. In terms of cover crops, the samples under the mshai tree were significantly higher in soil organic matter content than the

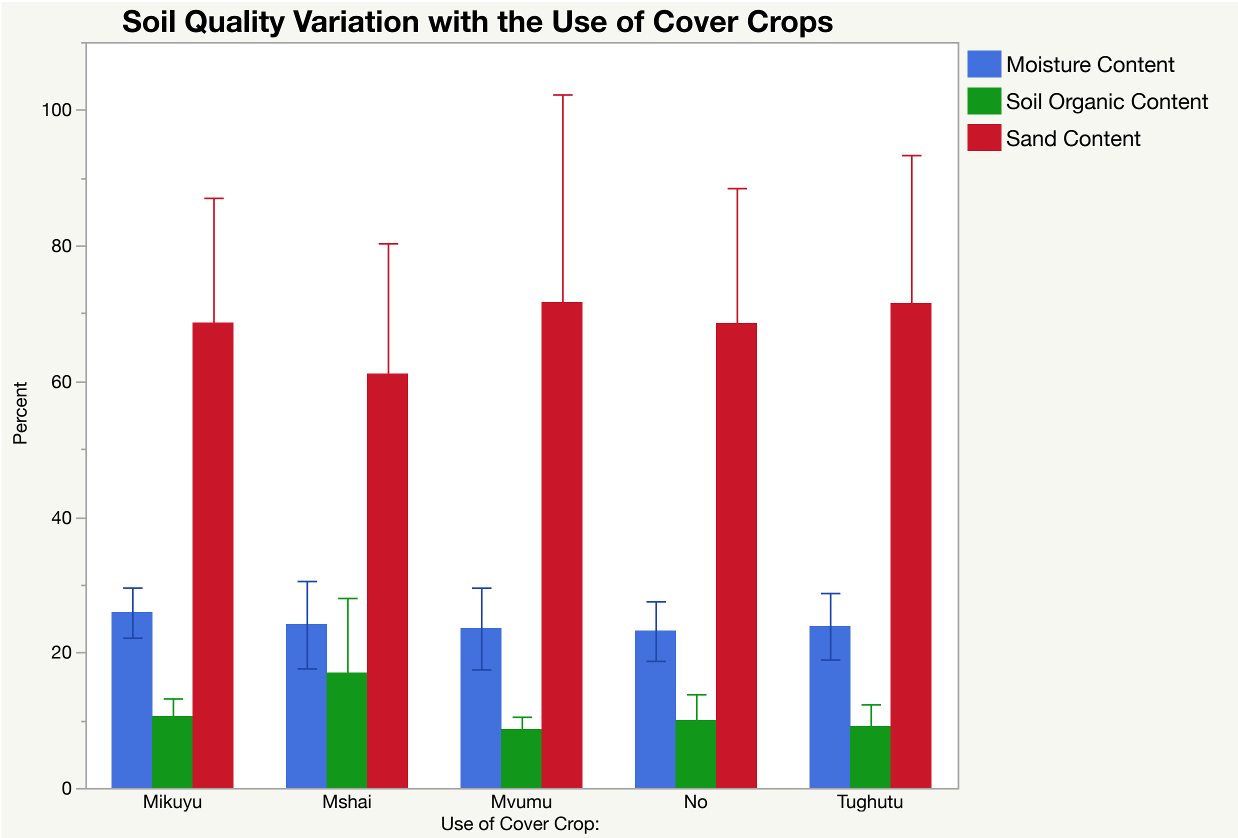


Figure 11 - A visualization of the relationship between average moisture content, soil organic matter, and sand content between samples either under no cover crops, or mikuyu, mshai, mvumu, or tughutu plants. Error bars are represented by the standard deviations.

samples under no cover crop (with a p-value of 0.0354). The samples collected under mikuyu trees had a higher organic matter content than the samples under no cover crops even though the relationship was not significant. There were no statistical differences between the different cover crop categories in terms of sand content or moisture content. Information about the impact of cover crops on soil quality is found in fig. 11. The use of a crop rotation resulted in no significant differences for any of the three soil quality parameters. It was determined that samples taken from plots of land that utilized intercropping have a significantly higher sand content than the samples taken from plots that do not use intercropping (with a p-value of 0.0326) (Fig. 11). Farmers who tilled their land had soils with a significantly lower soil organic content and higher sand content than the farmers who did not till their land (p-values of 0.0364 and 0.0137 respectively). Moisture content was not significantly different between tilled and non-tilled land (fig. 12). The use of animal manure showed that the farmers who reported sometimes using animal manure had a significantly lower moisture content than the farmers who responded yes or

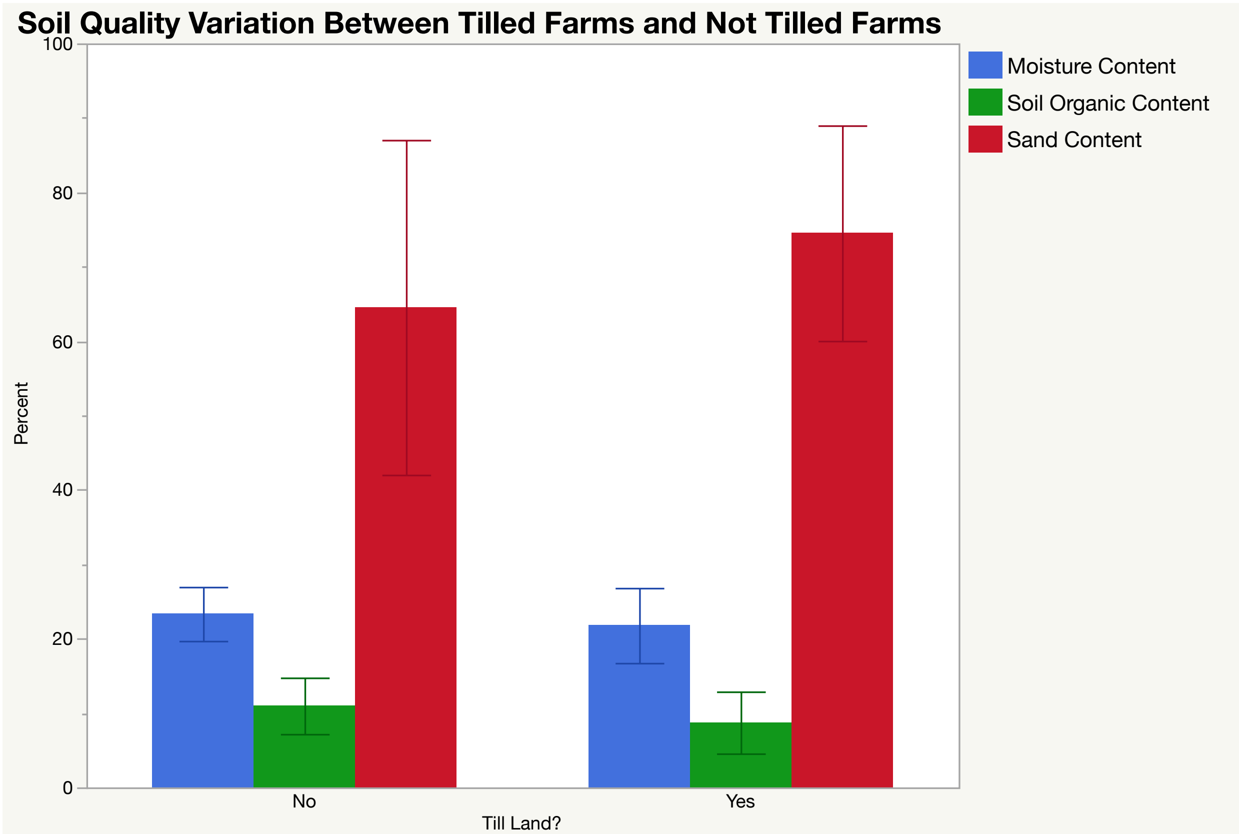


Figure 12 - A visualization of the relationship between average moisture content, soil organic matter, and sand content between farms that use tilling and not. Error bars are represented by standard deviations.

no (p-values of 0.0479 and 0.0428 respectively) (fig. 13). The use of chemical fertilizers, pesticides, and herbicide all showed no difference in the three soil quality parameters.

DISCUSSION:

The responses of the farmers made it clear that land degradation is an issue in Kizanda Village. Even with the majority of the farmers reporting that soil erosion isn't an issue they face on their farms, the responses to crop yield and soil quality changing highlight the need for improved soil conservation methods in Kizanda.

In terms of the effect that cultivating land has on soil quality, it was found that the soil samples in the Mazumbai Forest Reserve had significantly higher moisture contents than the samples collected at the farms and tea plantations. This is most likely due to the shading provided by the thick vegetation cover in the rainforest which prevents a lot of evaporation of water from the soils. A study conducted in Cameroon found that the conversion of forest to farmland reduced the silt content, moisture content, soil organic matter, nutrients, and pH while increasing the sand content (Tellen, 2018). Tellen's study supported this study's findings in terms of the moisture content difference. It is most likely that the other results found in Tellen's study were not replicated in this study because of the limited soil quality parameters analyzed. In addition, a study done in the West Usambaras found that the main driver of soil properties was the land use category (Massawe et al., 2018). Thus, it would be expected that the results form this study would highlight more of a difference between cultivated and uncultivated soil samples. Due to the results of these two findings, with more precise and widespread soil analysis methods, this study would most likely mimic the results from Tellen and Massage et al. more closely.

As discussed in the results above, some of the agricultural practices resulted in soil quality differences. The famers that tilled their land had lower soil organic matter content than the farmer who did not till their land. This is important information because around half of the famers tilled their land. Similarly, the use of cover crops was one practice that this study found to have a significant impact on soil quality. The use of mshai plants as cover crops showed higher resulting amount of soil organic matter in the soils, making them a great passive fertilizing technique. In addition, the mikuyu trees didn't show a significant impact on soil quality, but when collecting the samples it was noted that the soil was much darker, meaning it was healthier. This study most likely didn't have enough samples with the mikuyu plants to show a significant difference.

As seen in the results section, the remaining agricultural practices used in Kizanda showed no impact on soil quality. This can most likely be attributed to the lack of soil parameters tested and the precision level of analysis. However, the study done comparing Sustainable Land Use categories of farms (as mentioned in the Background section) found that the utilization of animal manure was not enough to change the nutrient content of the samples, so it showed no significance in the analysis (Wickama, et. al., 2014).

In terms of the impact that other factor have on the soil quality, this study showed no impact by general factors on soil quality that were also reflected in literature. However, a study done by Badai et al. found that with increasing elevation, the soil pH, content of fine particles such as silt/clay both increased and the soil organic matter and sand concentration decreased (2016). This study found no such results, most likely due to the small range of elevations sampled.

Bias and Limitations:

The most impactful limitation of this study was the methods of of soil sample analysis. This study was not able to test a wide variety of soil parameters. The soil analysis methods were the best that could be done with the available resources, but through data analysis, proved to be insufficient in some cases. First, the pH litmus blue paper that was used could only differentiate between acidic and non-acidic, and could not detect small differences in pH. This basically cut the soil quality parameters from four down to three because, as discussed above, all of the samples tested non-acidic. The soil organic content test was most likely a poor representation of the true amount of organic matter in the soils because the results were so scattered. The soil texture test was limited to just differentiating between sand and silt/clay due to the amount of time to process all the soil samples.

Due to the lack of transportation to and around Kizanda, it was too difficult to sample farms that were far away from the farmers' homes. This most likely skewed the data because often the agricultural practices used by farmers is in part determined by how far they have to walk to their farm (A. Mhema, personal communication, November 2019).

Recommendations:

This study found that avoiding tilling farm land, and the use of mshai trees as cover crops corresponded to higher soil quality. If these agricultural practices are more widely used throughout Kizanda, farmers could potentially keep high crop yields year to year. Due to the limitations discussed above, no further recommendations can be made.

This study did not utilize a laboratory to analyze data, so the methods could not differentiate similar soils in terms of specific parameters like pH, nitrogen concentration, phosphorus concentration, clay or silt content, and other parameters. Doing the same study again but using a lab to analyze the soil could discover a more specific and useful assessment of how agricultural practices impact the soil quality. With more specific information, suggestions could be made to farms with more confidence. In addition, doing a similar soil conservation study over multiple years could assess the rate of land degradation occurring and might call more attention to the issue.

CONCLUSION:

Small-scale agricultural operations are important to study so that the diverse agricultural practices used around the world can be analyzed in terms of sustainability. With the utilization of agricultural practices that conserve the soil's quality, crop yields will remain high. Sustainable agriculture will protect the vulnerable global communities who's life is dependent on the productivity of the land. This study found that cultivated soils have a lower moisture content. In other studies, cultivation led to sandier soils, less organic matter, less nutrients, and a lower pH.

This study also found that soil from untilled farms and soil near the mshai trees cover crops had higher soil quality. Thus, no-till agriculture and the use of cover crops like mshai should be utilized by more famers in Kizanda. The adoption of more sustainable agriculture will both protect livelihoods and limit land degradation.

REFERENCES:

Burgess, N.D., Butynski, T.M., Cordeiro, N.J., Doggart, N.H., Fjeldsa, J., Howell, K.M., Kilahama, F.B., Loader, S.P., Lovett, J.C., Mbilinyi, B., Mengegon, M., Moyer, D.C., Nashanda, E., Perkin, A., Rovero, F., Stanley, W.T., Stuart, S.N. (2007). The Biological Importance of the Eastern Arc Mountains of Tanzania and Kenya. *Biological Conservation, 134*, 209–231., doi:10.1016/j.biocon.2006.08.015.

D'Hoore, J., (1964) La carte des sols d'Afrique au 1:5000000. Memoire explicatif. *CCTA publish*, *93*. 209

Durigan, M., Cherubin, M., Camargo, P., Ferreira, J./, Berenguer, E., Gardner, T., Barlow, J., Dias, C., Signor, D., Junior, R., Cerri, C. (2017). Soil Organic Matter Responses to Anthropogenic Forest Disturbance and Land Use Change in the Eastern Brazilian Amazon. *Sustainability, 9*

FAO. (2014). Tanzania Country Programming Framework January 2014 – June 2016. *Food and Agricultural Organization of the United Nations. http://www.fao.org/3/a- bp609e.pdf*

Galford, G (2013) East African Montane forests, in R. W. Howard (ed), *Biomes and Ecosystems, Salem Press: Arena, NY*

Gillespie, C., (2019). How to Use Litmus Papers. *Sciencing, 2* sciencing.com/use-litmus-papers-4745370.html.

IPBES (Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services) (2018). Summary for policymakers of the thematic assessment report on land degradation and restoration of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. R. Scholes, L. Montanarella, A. Brainich, N. Barger, B. ten Brink, M. Cantele, B. Erasmus, J. Fisher, T. Gardner, T. G. Holland, F. Kohler, J. S. Kotiaho, G. Von Maltitz, G. Nangendo, R. Pandit, J. Parrotta, M. D. Potts, S. Prince, M. Sankaran and L. Willemen (eds.). Bonn, Germany: IPBES secretariat.

Kideghesho, J. R., (2015) Realities on Deforestation in Tanzania — Trends, Drivers, Implications and the Way Forward. *Precious Forests - Precious Earth,* doi: 10.5772/61002.

Lal, R., (1985). Soil erosion and sediment transport research in tropical Africa. *Hydrological Sciences Journal 30*, 117- 34.

Lundgren, Lill. (1980). Comparison of Surface Runoff and Soil Loss from Runoff Plots in Forest and Small-Scale Agriculture in the Usambara Mts., Tanzania. *Geografiska Annaler: Series A, Physical Geography*, *62,* 113–148., doi: 10.1080/04353676.1980.11880005.

Massawe, B. H. J., Winowiecki, L., Meliyo, J., Mbogoni, J., Msanya, B., Kimaro, D., Deckers, J., Gulinck, H., Lyamchai, C., Sayula, G., Msoka, E., Vagen, T., Brush, G., Jelinski, N.

(2011). Assessing drivers of soil properties and classification in the West Usambara mountains, Tanzania. *Geoderma Regional, 11*, 141–154.

Maboko, M.A.H., Nakamura, E., (2002). Isotopic dating of Neoproterozoic crustal growth in the Usambara Mountains of northeastern Tanzania: evidence for coeval crust for- mation in the Mozambique Belt and the Arabian-Nubian Shield. *Precambrian Res. 113*, 227–242. http://dx.doi.org/10.1016/ S0301-9268(01)00213-3.

Mbaga-Semgalawe, Zainab, and Henk Folmer. (2000). Household Adoption Behaviour of Improved Soil Conservation: the Case of the North Pare and West Usambara Mountains of Tanzania. *Land Use Policy, 17,* 321–336., doi:10.1016/s0264-8377(00)00033-8.

Ministry of Tourism, Natural Resources and Environment (MTNRE). (1994). Tanzania National Environment Action Plan: A First Step, Dar es Salaam.

Newmark, W. D. (1998). Forest Area, Fragmentation, and Loss in the Eastern Arc Mountains: Implications For the Conservation of Biological Diversity. *Journal of East African Natural History, 87,* 29–36., doi: 10.2982/0012-8317(1998)87[29:fafali]2.0.co;2.

Reves-Sohn, S. (2018). Soil Analysis of Mazumbai Forest Reserve Altitudinal Bands in Lushoto District, Tamzania. *Independent Study Project (ISP) Collection*.

Robinson. (2014). Sampling in interview-based qualitative research: A theoretical and practical guide. *Qualitative Research in Psychology*

Smith-Helman, Bailey. (2017). Agricultural Responses to Climate Change: A Study of Adaptive Methods in Kizanda Village. *Independent Study Project (ISP) Collection*. https://digitalcollections.sit.edu/isp_collection/2703

Tellen, V. A., & Yerima, B. P. K. (2018). Effects of land use change on soil physicochemical properties in selected areas in the North West region of Cameroon. Environmental Systems Research, 7. https://doi.org/10.1186/s40068-018-0106-0

USDA. (2001). *Guidelines for Soil Quality Assessment in Conservation Planning*. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051259.pdf

Winowiecki, L., Vågen, T., Massawe, B., Jelinski, N.A., Lyamchai, C., Sayula, G., Msoka, E. (2015). Landscape-Scale Variability of Soil Health Indicators: Effects of Cultivation on Soil Organic Carbon in the Usambara Mountains of Tanzania. *Nutrient Cycling in Agroecosystems.105*. 263–274. doi:10.1007/s10705-015-9750-1.

Wickama, J., Okoba, B., & Sterk , G. (2014). Effectiveness of sustainable land management measures in West Usambara highlands, Tanzania. *Catena, 118*, 91–102.

World Bank. (2019). Tanzania: Country Environmental Analysis – Environmental Trends and Threats, and Pathways to Improved Sustainability. 2019. Washington, DC: World Bank.

APPENDIX I:

Questions for Farmers:

1. What is your name?

2. How big is your farm?

3. How long have you been farming on this land?

4. Have you noticed a change in the soil quality?

If so, what changes?

5. Have you noticed any change in your crop yield over time?

6. Which of these crops do you grow?

Maize, beans, banana, coffee, tea, cassava, potato, sweet potato, onion, garlic,

cabbage, carrot, spinach, chinezi, mboga mboga, tomato, bitter tomato, broccoli, squash, papaya, avocado?

Any other crops?

7. Do you use irrigation?

If so what kind?

8. Do you use intercropping?

9. Do you use cover crops?

If so which ones?

10. Do you use fertilizers?

If so: Chemical? Compost? Poultry manure? Cow manure? Goat manure? Anything else?

11. Do you use crop rotation?

If so, can you explain it?

12. Do you till you land?

13. Do you use pesticides or herbicides?

14. Have you always been using these same methods that I've been asking you about?

15. Would you mind if I take some soil samples of your farm?

APPENDIX II:

Avocado?	Suagr Cane?	Fruit Trees?	Coco Yams?	Leeki?	Decrease in crop yeild over time?	Decrease in soil quality?	Is soil erosion an issue?	Soil erosion mitigation?	Irrigation?	Intercropping?	Cover crops?	Crop Rotation?	Till your land? (by hand)	Pesticides?	Herbicides?	Fertilizer: Animal Manure?	Fertilizer: Poultry Manure?	Fertilizer: Chemical?	Always the same methods?	Soil Sample ID:
no	yes	no	no	no	yes	yes	no	no	no	yes	no	no	yes	no	no	yes	no	no	yes	1
no	no	yes	no	no	yes	yes	no	no	During drought season	yes	Mikuyu	yes	yes	no	no	yes	no	no	yes	2
no	no	no	no	no	no	no	no	no	some parts of farm	yes	Tughutu	no	Yes	no	No	yes	no	yes	yes	3
no	no	no	no	no	yes	yes	no	Plant trees	some parts of farm	yes	Kikuyu trees, muombe ombe, mvumu, mshai	Yes	yes	perfecton	Roundup	yes	yes	yes	yes	4
no	no	no	yes	no	yes	yes	yes	Plant trees	yes	yes	Yes, tughutu, miwkewuyu	yes	No	Yes	no	yes	yes	No	yes	5
no	no	yes	yes	no	no	no	yes	Plant trees	no	yes	no	yes	No	No	no	yes	yes	no	yes	6
yes	no	yes	yes	no	no	no	yes	Plant trees	yes	yes	yes, fruit trees	No	yes	no	no	yes	yes	Urea	yes	7
no	no	no	yes	no	yes	yes	yes	Channels to divert water	During drought season	yes	yes, tughutu	yes	No	Yes	Roundup	yes	no	no	yes	8
no	no	no	yes	no	no	no	no	no	no	no	no	no	No	no	No	yes	no	no	yes	9
no	no	no	yes	yes	yes	yes	no	no	no	yes	no	yes	yes	no	no	yes	yes	no	yes	10
no	no	no	yes	yes	yes	yes	yes	plant grasses and trees	no	yes	yes, mikuyu, mshai, and tughutu	no	No	no	no	yes	yes	no	yes	11
no	no	no	yes	yes	no	no	no	no	During drought season	yes	yes, mshai trees, mvumu	yes	No	Sometimes	no	yes	yes	no	yes	12
no	no	no	yes	No	yes	yes	no	no	no	yes	no	yes	No	Yes	no	yes	yes	Urea and Dup	No	13
no	no	no	yes	yes	yes	yes	no	no	some parts of farm	yes	yes, mikuyu trees, mvumu, tughutu	yes	yes	sicron	no	yes	yes	no	yes	14
Yes	no	yes	yes	yes	yes	yes	no	no	no	yes	yes, tughutu	yes	yes	no	no	yes	yes	no	yes	15
no	no	no	yes	yes	no	no	yes	plant trees	no	yes	no	no	no	no	no	yes	yes	no	yes	16
no	no	no	no	no	yes	no	no	no	no	no	yes, mshai trees, mvumu	no	no	yes	no	no	no	Yes	yes	17
no	no	no	no	no	yes	no	no	no	no	no	no	no	no	no	roundup	no	no	no	yes	18
no	no	no	no	no	yes	yes	no	no	no	no	yes, mikuyu	no	no	no	roundup	no	no	used to	yes	19
no	no	no	No	no	yes	yes	no	no	yes	yes	no	yes	yes	Yes	no	yes	Yes	Yes	yes	23
no	no	no	yes	no	no	no	no	no	During drought season	yes	no	no	no	no	no	yes	Yes	no	yes	24
no	no	no	no	no	yes	yes	yes	yes, plants and animal grasses	no	yes	no	no	no	no	no	yes	Yes	no	yes	25
no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no	No	no	yes, NPK	yes	26
no	no	no	no	no	yes	yes	no	no	no	yes	yes, tughutu	no	yes	no	no	Sometime s	no	no	yes	27
no	no	no	yes	no	yes	no	yes	no	no	yes	no	yes	yes	boost up sometimes	no	yes	Yes	no	yes	28
no	no	no	no	no	yes	no	no	no	yes	yes	no	yes	yes	no	no	yes	Yes	no	yes	29
																				30
no	no	no	no	no	yes	yes	no	no	no	no	yes, mshai	no	no	no	no	no	no	no	yes	31
no	no	no	no	no	no	no	no	no	no	no	yes, mshai	no	no	no	no	no	no	no	yes	32

h?	Papaya?
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no
	no

Table 1 - Answers to the questions asked of farmers in Kizanda Village.

Plant in Sambaa:	**Scientific Name:**
Tughutu	Vernon subligera
Mvumu	Ficus craterostoma
Mshai	Albizia gummier
Mikuyu	Ficus Sycomorus Ficus Thonningii Ficus Vallis-Choudae

Table 2 - Cover crop plant names in Sambaa language and their respective scientific names. Translated by Mr. Kiparu.

APPENDIX III:

NUTS AND BOLTS

Location: Mazumbai

Transport:
There is a bus from Arusha to Soni (somewhere between 15,000 and 20,000 TSH). Then David can pick you up in Soni and drive you up to the Mazumbai chalet. The total for the car was 90,000ish TSH. Davis is great and will be there right when you get off the bus and make the process less stressful. David's phone number is +255 786 364. Same transportation deal on the way back to Arusha.

Room and Board:
I stayed in a room with one other person, we each payed $5 per night…can't beat that price! Depending on the time of year, it can get very cold at Mazumbai, so if you have room in your luggage, I would recommend bringing a sleeping bag or blanket.

Food:

Mazumbai is very very isolated, so you can't buy your own food. We paid David 20,000 TSH to drive down to town and pick up groceries for us each week. We paid around 70,000 TSH per person per week on food. In addition, we paid Zwena (Beatrice) a flat rate of 20,000 TSH per day for food for the whole group. She made us many delicious meals along the lines of veggies/rice/beans/pasta. I would suggest bringing lots of snacks like cookies and candy because it's harder to get that kind of food once you are at Mazumbai. There is a small shop downhill from the Mazumbai house which has lollipops which became a huge moral booster. You should also try and bring your own alcohol to Mazumbai if you will want it, however it is possible to get beer with David.

Translator/Forest Guides:
My translator was named Ashiraz Mhema, he was super chill and super helpful throughout the whole ISP process. He might not be around for other semesters, but you should ask Kiparu about him. If he is gone, not to worry, Kiparu will set you up with someone else. Edy was my forest guide for a few days, he is also really nice and extremely knowledgeable about the forest. Kiparu sets the prices for translators and forest guides. It is a fixed rate per day at 20,000 TSH / Day to work with a translator and 15,000 TSH / Day to work with a forest guide.

Additional Notes:
Another thing to keep in mind is that there is no WiFi at mazumbai, so you will need to bring a modem to convert cell service into data. We ended up using Oscar's, but you may have to buy one if his isn't available. Also, be ready to get frustrated with laundry because it is so wet in the area so clothes take a long time to dry. Mazumbai is very isolated which was definitely a challenge. Make sure to bring cards, books, and any other activities you can think of. Also we went into the rainforest at night one time which was really cool, I would highly recommend. Also definitely build a rest day into your schedule, I walked around 7 miles a day into Kizanda and really needed a break every week. Also be ready to deal with some sexism and favoritism within the Mazumabi staff. We had one male in our group and often he was the only one addressed in the group… very frustrating. Also the staff will most likely be expecting tips at the end of your stay.